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BOREAS HYD-9 Tipping Bucket Rain Gauge Data

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BOREAS HYD-9 Tipping Bucket Rain Gauge Data

Nicholas Kouwen, Ric Soulis, Wayne Jenkinson, Allyson Graham, Todd Neff

Summary

The BOREAS HYD-9 team collected several data sets containing precipitation and streamflow measurements over the BOREAS study areas. This data set contains the measurements from the tipping bucket rain gauges at the BOREAS NSA and SSA. These measurements were submitted in 15-minute and 1-hour intervals. Only the 15-minute interval data set was loaded into the data base tables. Data were collected from the tipping bucket gauges from mid-April until mid-October in 1994, 1995, and 1996. The data are available in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS HYD-09 Tipping Bucket Rain Gauge Data

1.2 Data Set Introduction

This data set contains the measurements from the tipping bucket rain gauges at the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) and Southern Study Area (SSA). These measurements were submitted in 15-minute and 1-hour intervals. Only the 15-minute interval data set was loaded into the data base tables. Data were collected from the Belfort gauges from mid-April until mid-October in 1994, 1995, and 1996.

1.3 Objective/Purpose

This project will seek to identify, through field measurements and computer modeling, the space-time distribution of meltwater supply to the soil during the spring melt period and the evolution of soil moisture, evaporation, and runoff from the end of the snowmelt period through freeze up. The

snow modeling activity will consist of two components. The first will use existing "off-the-shelf" models to forecast the onset and spatial extent of snowmelt and meltwater supply to the soil column prior to the 1994 Intensive Field Campaigns (IFCs). The second phase will extend, implement, and verify a physically based energy balance snowmelt model of the two sites and will evaluate approaches to aggregating detailed snowmelt predictions and measurements based on the model to larger scales, up to the size of a rectangle of several hundred km containing the northern and southern sites. The soil moisture modeling is based on a grouped response unit method that will allow characterization of soil moisture, evaporation, and runoff for the entire northern and southern sites.

1.4 Summary of Parameters

The following phenomena and their parameters are being reported: precipitation amount in a 15-minute period.

1.5 Discussion

The locations for 12 tipping bucket measuring devices, 10 Belfort gauges, and 5 stream sites were selected within the two BOREAS study sites (NSA and SSA). These instruments were installed during the 1994 Focused Field Campaign-Thaw (FFC-T) in the last week of April. They were in operation until October 1994, when they were removed from service. The tipping buckets and Belfort gauges provided an approximate measure of the precipitation in the study areas, and the discharge rates of the streams provided a measurement of water leaving the study area. When used together, these two sets of data provide a balance of the water cycle. Similar measurements were collected in 1995 and 1996 from approximately April to October of those years.

1.6 Related Data Sets

BOREAS HYD-09 Belfort Rain Gauge Data
BOREAS HYD-09 Stream Flow Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

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2.2 Title of Investigation

From Micro-Scale to Meso-Scale Snowmelt, Soil Moisture and Evapotranspiration from Distributed Hydrologic Models

2.3 Contact Information

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3. Theory of Measurements

A tipping bucket gauge consists of a conical funnel attached to the top of a cylinder for support. It is designed to find the vertical depth of water that would accumulate on a level surface if the precipitation remained where it fell. A small container separated into two parts is located underneath the funnel. One of these parts, a bucket, is angled beneath the funnel where it can collect water. When one of the buckets is filled with a specific amount of rain (usually 0.1 or 0.2 mm), it tips down and releases the water into a reservoir. This tipping action brings the other bucket up into place beneath the funnel much as a teeter totter would. The container must be balanced correctly in order to achieve this motion. When the bucket tips down, it activates a switch that prompts a data logger to record the information. Because it is already known exactly how much water causes the bucket to drop (through calibration), a graph of precipitation versus time can be created.

4. Equipment

4.1 Sensor/Instrument Description

Tipping Bucket:
A tipping bucket gauge is a device used to measure the amount of precipitation in a given area. When a specific amount of rainfall fills one of the buckets, the bucket tips and triggers a switch. The accumulated number of bucket tips is recorded at regular intervals by an electronic data logger. One of the tipping bucket gauges (TB-SW2) had a 9.664-inch diameter opening, and the buckets were tipped after 0.1 mm of rainfall. The other tipping bucket gauges had 12-inch diameter openings, and the buckets were tipped after 0.2 mm of rainfall.

Data Logger:
The chart pac CP-X data logger was connected to the tipping bucket rain gauge and programmed to record the cumulative number of tips that occurred in a 15-minute period. The data logger stored the information in its memory until it was retrieved.

4.1.1 Collection Environment
The equipment was operated in variable ambient atmospheric conditions at the field sites in Saskatchewan and Manitoba during 1994.

4.1.2 Source/Platform

Tipping buckets were mounted on a wide wooden base placed on the ground. The data loggers were mounted inside watertight containers placed adjacent to the tipping buckets.

4.1.3 Source/Platform Mission Objectives

In order to make sufficient precipitation data, a detailed estimate of the total amount of precipitation must be collected to account for all peak periods of precipitation and any variations that occur with time. To achieve this, the data were recorded at regular intervals of 15 minutes. The data logger stored the information until it was retrieved. Tipping bucket and Belfort gauges were used to provide independent measures of precipitation in order to reduce errors.

4.1.4 Key Variables

- Tipping Buckets - Precipitation amount in a 15-minute period
- Data Logger - Voltage

4.1.5 Principles of Operation

The tipping bucket is a self-contained device designed to measure the amount of precipitation occurring in a given area over time. It is only an estimate of the total rainfall in an area. The amount of water is measured by the triggering of a weight-activated switch whenever a certain volume of water has fallen.

4.1.6 Sensor/Instrument Measurement Geometry

The tipping bucket gauge is mounted at ground level. It must be in a clearing large enough so that a 45-degree inverted cone originating from its highest point can reach the atmosphere unimpeded. If trees or other obstructions are surrounding the tipping bucket, they will affect the data. The device should be mounted on a stable base (example: a wooden platform) and leveled so that the cone is completely vertical (i.e., axis of gauge is perpendicular to a water level).

4.1.7 Manufacturer of Sensor/Instrument

Tipping Bucket Gauges - Environmental Measurements Ltd.
ARG 100 Rain Gauge
3 Stepcentre
Osney Mead, Oxford, England
OX2 0ES
011-44-0865-724-240

Texas Electronics, Inc.
5529 Redfield St.
P.O. Box 7225
Inwood Station
Dallas, TX 75209
(214) 631-2490

Data Logger - Lakewood Systems
Edmonton, Alberta, Canada
(403) 462-9211

4.2 Calibration

A tipping bucket is calibrated by slowly pouring a known amount of water into the funnel and counting how many bucket tips occur. This will allow for the calculation of the exact volume of water per bucket tip, which can be compared to the device's specifications. For example, if the company says that the bucket will tip when the bucket is filled with 4.73 ml of water and this amount is equivalent to 0.1 mm of rainfall, but the calibration shows that the device actually holds 5.00 ml per bucket tip, then this amount is equivalent to 0.106 mm of rainfall ([5.0/4.73] * 0.1 mm = 0.106 mm of

precipitation).

4.2.1 Specifications

Tipping Bucket - orifice opening: 12-inch diameter opening on 11 of the gauges; TB-SW2 (called SSA-TB7-HYD09-TBRG07 in the data base) has a 9.664-inch diameter opening.

Frequency of tipping action: every 0.2 mm of rainfall for 11 of the gauges; TB-SW2 (called SSA-TB7-HYD09-TBRG07 in the data base) tips after 0.1 mm of rainfall.

4.2.1.1 Tolerance

A tipping bucket can measure an infinite amount of water (if data storage is unlimited) in increments of 0.2 mm or 0.1 mm of rainfall. The recorded rainfall is within 1.0% of the actual rainfall amount when the amount of rainfall is 2 inches per hour or less. When the rainfall rate exceeds 2 inches per hour, water may spill over the edges of the bucket and not be counted.

4.2.2 Frequency of Calibration

The tipping buckets were calibrated once at the beginning, the middle, and the end of the study period.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

A data logger recorded the precipitation data for the tipping bucket gauges. The data logger was connected to a notebook computer onsite, where the logger's stored information was transferred to the notebook. The number of tips was then converted to precipitation and checked for quality.

6. Observations

6.1 Data Notes

Instrument	Year	Date	Event
Tipping Bucket 1, Tipping Bucket 10	1994	10-APR	TB1 installed
		16-OCT	TB1 removed
Note: TB 1 was moved May 31, 1995, and renamed TB 10	1995	11-APR	TB1 installed
		18-APR - 26-APR	Missing data - mechanical problems
		06-MAY- 31-MAY	Missing data - mechanical problems
		31-MAY	TB1 removed
		01-JUN	TB10 installed at new location
		01-JUN - 06-JUL	Missing data - mechanical problems
		07-NOV	TB10 removed
	1996	15-APR	TB10 installed
		15-APR - 26-JUL	Missing data
		26-JUL	Battery flat - logger recharged and started with 226 tips
		06-NOV	TB10 removed

Instrument	Year	Date	Event
Tipping Bucket 2	1994	11-APR	TB2 installed
		17-OCT	TB2 removed
	1995	11-APR	TB2 installed
		07-NOV	TB2 removed
	1996	01-APR	TB2 installed
		25-JUL - 19-AUG	Missing data
		06-NOV	TB2 removed
Tipping Bucket 3	1994	11-APR	TB3 installed
		25-MAY	Missing data
		18-OCT	TB3 removed
	1995	11-APR	TB3 installed
		07-NOV	TB3 removed
	1996	16-APR	TB3 installed
		27-MAY- 05-JUN	Missing data
		06-NOV	TB3 removed
Tipping Bucket 4	1994	12-APR	TB4 installed
		17-OCT	TB4 removed
	1995	26-APR	TB4 installed
		15-JUL -08-NOV	Missing data
		08-NOV	TB4 removed
	1996	01-APR	TB4 installed
		06-NOV	TB4 removed
Tipping Bucket 5	1994	20-APR	TB5 installed
		17-OCT	TB5 removed
	1995	-	Not installed
	1996	-	Not installed
Tipping Bucket 6, Tipping Bucket 6A Note: TB6 was moved July 15, 1996, and renamed TB6A	1994	04-MAY	TB6 installed
		17-OCT	TB6 removed
	1995	12-APR	TB6 installed
		08-NOV	TB6 removed
	1996	16-APR	TB6 installed
		15-JUL	Moved to Old Black Spruce (OBS) Tower, renamed TB6A
		06-NOV	TB6A removed
Tipping Bucket 7	1994	04-MAY	TB7 installed
		16-OCT	TB7 removed
	1995	11-APR	TB7 installed
		09-MAY - 12-MAY	Missing data
		07-NOV	TB7 removed
	1996	16-APR	TB7 installed
		06-NOV	TB7 removed
Tipping Bucket 8	1994	-	Not installed
	1995	12-MAY	TB8 installed
		08-NOV	TB8 removed
	1996	27-JUL	TB8 installed
		12-OCT	TB8 removed

Instrument	Year	Date	Event
Tipping Bucket 9, Belfort 4	1994	-	Installed as Bel4 - see Belfort information
	1995	12-MAY	TB9 installed
		08-NOV	TB9 removed
Note: Was installed as Bel4 in 1994, TB9 in 1995 and 1996	1996	23-AUG	TB9 installed
		06-NOV	TB9 removed
Tipping Bucket 21, Belfort 24	1994	27-APR	TB21 installed
		27-APR - 18-MAY	Missing data
		14-OCT	TB21 removed
Note: TB21 was installed as Bel24 in 1995 and 1996	1995	-	Installed as Bel24 - see Belfort information
	1996	-	Installed as Bel24 - see Belfort information
Tipping Bucket 22	1994	26-APR	TB22 installed
		18-MAY	Missing data
		12-JUL	Spider's nest found in tipping bucket. Water stored in nest released and recorded as precipitation. Evaporation losses likely.
		22-JUL - 23-JUL	Missing data
		14-OCT	TB22 removed
	1995	29-APR	TB22 installed
		10-NOV	TB22 removed
	1996	-	No reasonable data
Tipping Bucket 23	1994	27-APR	TB23 installed
		14-OCT	TB23 removed
	1995	29-APR	TB23 installed
		10-NOV	TB23 removed
	1996	15-APR	TB23 installed
		*	partial record
		06-NOV	TB23 removed
Tipping Bucket 24, Belfort 25	1994	27-APR	TB24 installed
		14-OCT	TB24 removed
Note: TB24 was installed as Bel25 in 1995 and 1996	1995	-	Installed as Bel25 - see Belfort information
	1996	-	Installed as Bel25 - see Belfort information
Tipping Bucket 25	1994	28-APR	TB25 installed
		14-OCT	TB25 removed
	1995	16-MAY	TB25 installed - daily values until 06/18
		16-NOV	TB25 removed
	1996	13-APR	TB25 installed
		24-OCT	TB25 removed
Tipping Bucket 26, Belfort 21	1994	-	Installed as Bel21 - see Belfort information
	1995	29-APR	TB26 installed
		24-AUG	Gauge leveled, logger restarted
Note: Was installed as Bel21 in 1994, TB26 in 1995 and 1996		10-NOV	TB26 removed
	1996	-	No reasonable data

Instrument	Year	Date	Event
Tipping Bucket 27,	1994	-	Installed as Bel23 - see Belfort information
Belfort 23	1995	29-APR	TB27 installed
Note: Was installed		04-JUL - 01-AUG	Missing data
as Bel23 in 1994,		10-NOV	TB27 removed
TB27 in 1995 and 1996	1996	14-APR	TB27 installed
		10-JUN	Gauge found knocked over and damaged - replaced and reset
		25-OCT	TB27 removed
Tipping Bucket 28,	1994	-	Installed as Bel22 - see Belfort information
Belfort 22	1995	-	No reasonable data
Note: Was installed	1996	-	No reasonable data
as Bel22 in 1994,			
TB28 in 1995 and 1996			
Tipping Bucket 29	1996	02-JUN	TB29 installed
Note: Was installed		25-OCT	TB29 removed
very near TB28			
as a backup gauge			

6.2 Field Notes

None given.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

Twelve tipping buckets were set within and around the boundaries of the water basins to give an estimate of the precipitation within these boundaries. Each tipping bucket gauge was a point measurement of the precipitation, making the total area of coverage very small. From these point measurements, the average precipitation for the study basins could be estimated. Together, they represent the total rainfall in the area. The size of both northern water basins being studied is 27 km^2, while the size of the southern water basin is 574 km^2. The following table lists the tipping bucket rain gauges used and their locations. These coordinates are in the North American Datum of 1983 (NAD83).

SITE_ID	LONGITUDE	LATITUDE
NSA-T21-HYD09-TBRG21	98.34275W	55.91236N
NSA-T22-HYD09-TBRG22	98.43671W	55.88842N
NSA-T23-HYD09-TBRG23	98.37767W	55.88866N
NSA-T24-HYD09-TBRG24	98.56599W	55.92662N
NSA-T25-HYD09-TBRG25	98.44883W	55.91119N
NSA-T26-HYD09-TBRG26	98.4111W	55.88856N
NSA-T27-HYD09-TBRG27	98.55822W	55.89147N
NSA-T28-HYD09-TBRG28	98.49892W	55.77653N
NSA-T29-HYD09-TBRG28	98.49892W	55.77653N
SSA-TB1-HYD09-TBRG01	105.13441W	53.93336N
SSA-TB2-HYD09-TBRG02	104.73677W	53.98388N

SSA-TB3-HYD09-TBRG03	104.70427W	54.04309N	
SSA-TB4-HYD09-TBRG04	104.87348W	54.15781N	
SSA-TB5-HYD09-TBRG05	104.93682W	54.05218N	
SSA-TB6-HYD09-TBRG06	105.11288W	53.99847N	
SSA-T6A-HYD09-TBRG6A	105.1170W	53.99872N	(approximated)
SSA-TB7-HYD09-TBRG07	104.68167W	53.895N	
SSA-TB8-HYD09-TBRG08	104.89617W	54.00469N	
SSA-TB9-HYD09-TBRG09	104.93681W	54.05247N	
SSA-T10-HYD09-TBRG10	105.14389W	53.91883N	

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
Because the data were gathered as point measurements, the resolution of the resultant data is very low. They are meant only to give the average precipitation rates at 15-minute intervals for the study basins.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
Data were collected from the tipping bucket gauges from mid-April until mid-October in 1994, 1995, and 1996.

7.2.2 Temporal Coverage Map
Not available.

7.2.3 Temporal Resolution
Measurements were recorded by the tipping bucket gauges at 15-minute intervals.

7.3 Data Characteristics

7.3.1 Parameter/Variable
The parameters contained in the data files on the CD-ROM are:

Column Name
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
PRECIPITATION
PARM_VALUE_FLAGS
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what is means will vary with site types.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
PRECIPITATION	The amount of precipitation measured by the rain gauge for the 15 minute period preceding the given time.
PARM_VALUE_FLAGS	This contains values or codes that indicate special conditions for the data parameters. See data set documentation for descriptions of these codes.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
PRECIPITATION	[millimeters]
PARM_VALUE_FLAGS	[none]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Supplied by Investigator]
TIME_OBS	[Supplied by Investigator]
PRECIPITATION	[Supplied by Investigator]
PARM_VALUE_FLAGS	[Supplied by Investigator]
CRTFCN_CODE	[Assigned by BORIS]
REVISION_DATE	[Assigned by BORIS]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-999-TRG21	SSA-999-TRG06	None	None	None	None
SUB_SITE	HYD09-TRG01	HYD09-TRG25	None	None	None	None
DATE_OBS	10-APR-94	07-NOV-96	None	None	None	None
TIME_OBS	0	2345	None	None	None	None
PRECIPITATION	0	32.9	-999	None	None	None
PARM_VALUE_FLAGS	N/A	N/A	None	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	19-MAR-96	14-JUL-97	None	None	None	None

Minimum Data Value -- The minimum value found in the column.

Maximum Data Value -- The maximum value found in the column.

Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.

Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.

Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined that the parameter value was below the detection limit of the instrumentation.

Data Not Cllctd -- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.

```
Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
--------------------------------------------------------------------------------
```

7.4 Sample Data Record

The following are wrapped versions of data records from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,PRECIPITATION,PARM_VALUE_FLAGS,CRTFCN_CODE,
REVISION_DATE
'SSA-999-TRG05','HYD09-TRG05',01-JUN-94,0,0.0,'','CPI',19-MAR-96
'SSA-999-TRG05','HYD09-TRG05',01-JUN-94,15,0.0,'','CPI',19-MAR-96
```

8. Data Organization

8.1 Data Granularity

The smallest amount of data that can be ordered from this data set is a day's worth of data for a given site.

8.2 Data Format(s)

The Compact Disk-Read Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

After a tipping bucket has been calibrated, the amount of precipitation per measuring period can be found by using:

Total precipitation = # of tips * precipitation per tip i.e., 4.5 mm = 45 tips * 0.1 mm per tip

9.1.1 Derivation Techniques and Algorithms

At regular intervals during the monitoring period, the accumulated number of bucket tips that had occurred was recorded on a data logger. The bucket tips were then converted to precipitation using the calibration coefficient. If the tipping bucket was reset (data logger started to record from zero again), then the data were adjusted accordingly.

9.2 Data Processing Sequence

9.2.1 Processing Steps

The following steps were performed to collect the data:

- Set up necessary equipment.
- Record the number of bucket tips over time.
- Calculate the precipitation rates using a coefficient.
- Enter the precipitation rates into ASCII files with the appropriate identifying information noted beside each row (location, year, day, month).
- Add the necessary column headings.
- Transfer the information to the data base.

BORIS processed the data by:

- Reviewing the initial data files and loading them online for BOREAS team access.
- Designing relational data base tables to inventory and store the data.
- Loading the data into the relational data base tables.
- Working with the Hydrology (HYD)-09 team to document the data set. 5) Extracting the standardized data into logical files.

9.2.2 Processing Changes

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

None.

9.4 Graphs and Plots

See associated report file "hyd09_report.pdf" (an Adobe Acobat file).

10. Errors

10.1 Sources of Error

Most of the errors occur during the actual measuring of the precipitation. Some of the smaller sources of error occur from water splashing out of the funnel, water evaporating from the reservoir that cannot be measured, water used to initially wet the gauge's surface, and gauges that are not perfectly level.

A larger source of error is the wind, which can cause turbulent air flow around the gauge, creating updrafts and downdrafts that interfere with the normal path of precipitation. A high wind speed will also create compressed lines of flow, reducing the amount of precipitation that enters the gauge. The higher the wind speed, the greater the effect on the measured precipitation.

During high levels of precipitation, water is not measured precisely because of its high rate of flow. Extra water, in addition to what is required to tip the bucket, pours into the bucket while it is in the process of tipping. This extra water is not accounted for and is lost. If the collecting rim (funnel opening to the outside) is damaged in any way, the amount of precipitation being measured will be changed because less water enters the gauge than what it was calibrated for.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The effects of the wind were reduced considerably by placing the gauges in clearings surrounded by forest, which shielded the gauge from oncoming winds. To try to account for high precipitation rates, water was collected in an independent, manually read gauge and compared to what the data logger had recorded over the same time period. If the two methods were significantly different, corrections were made. After the information had been collected, it was run through an algorithm to detect any data that were abnormal when compared to the rest of the data. Computer programs were also used to adjust the gauges for periods when they had missing lids.

There may be anomalies in the data that could not be resolved at the time these data were published. Please consult the data notes (Section 6.1) for information that might give some indication about the source of any anomalies.

10.2.2 Confidence Level/Accuracy Judgment

The confidence level of the data varies with the particular tipping bucket gauge at the time of measurement.

10.2.3 Measurement Error for Parameters

The collected data will eventually be compared to radar data and the calibration measurements, but at this time no steps have been taken to carry this out.

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

Data that were loaded into the data tables were spot checked against the original ASCII data that were submitted to check for data loading errors.

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

See Section 6.1.

11.3 Usage Guidance

Because of the problems that occurred, some periods of precipitation are not accurate.

11.4 Other Relevant Information

HYD-09 wrote a report stored on this CD-ROM called "hyd09_report.pdf" (an Adobe Acobat file). It can be referenced as:

Kouwen, N., R. Soulis, W. Jenkinson, A. Graham, and T. Neff. 1997. BOREAS: Boreal Forest Hydrological Research Study. Hydrology 9 Group: From Micro-scale to meso-scale snowmelt, soil moisture and evapotranspiration from distributed hydrological models, University of Waterloo, Dept. of Civil Engineering, August 1997.

12. Application of the Data Set

These data can be used for precipitation distribution, soil moisture, and other hydrological studies.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Several computer programs are required to convert the data logger information into precipitation and to check it for quality.

14.2 Software Access

None given.

15. Data Access

The HYD-09 tipping bucket rain gauge data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products
None.

16.2 Film Products
None.

16.3 Other Products
These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation
Environment Canada: Atmospheric Environment Service. Tipping Bucket Rain Gauge System. 1981.

Hoskin Scientific Limited. 1992. Chart pac Cp-X (price and specification sheet).

Kouwen, N., R. Soulis, W. Jenkinson, A. Graham, and T. Neff. 1997. BOREAS: Boreal Forest Hydrological Research Study. Hydrology 9 Group: From Micro-scale to meso-scale snowmelt, soil moisture and evapotranspiration from distributed hydrological models, University of Waterloo, Dept. of Civil Engineering, August 1997.
Texas Electronics, Inc. (see 5.1.6). Remote Reading Electric Rain Gauge (specification sheets).

17.2 Journal Articles and Study Reports
Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102 (D24): 28,731-28,770.

17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms

None.

19. List of Acronyms

AES	- Atmospheric Environment Service of Canada
ASCII	- American Standard Code for Information Interchange
Bel	- Belfort Gauge
BOREAS	- BOReal Ecosystem-Atmosphere Study
BORIS	- BOREAS Information System
CD-ROM	- Compact Disk (optical), Read-Only Memory
DAAC	- Distributed Active Archive Center
EOS	- Earth Observing System
EOSDIS	- EOS Data and Information System
FFC-T	- Focused Field Campaign - Thaw
GIS	- Geographic Information System
GMT	- Greenwich Mean Time
GSFC	- Goddard Space Flight Center
HYD	- Hydrology
IFC	- Intensive Field Campaign
NAD83	- North American Datum of 1983
NASA	- National Aeronautics and Space Administration
NSA	- Northern Study Area
OBS	- Old Black Spruce
ORNL	- Oak Ridge National Laboratory
PANP	- Prince Albert National Park
SSA	- Southern Study Area
TB	- Tipping Bucket
URL	- Uniform Resource Locator

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Kouwen, N., R. Soulis, and D. Knapp ,"From Micro-Scale to Meso-Scale Snowmelt, Soil Moisture and Evapotranspiration from Distributed Hydrologic Models." in Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A.Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. CD- ROM. NASA, 2000.

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS HYD-9 team collected several data sets containing precipitation and streamflow measurements over the BOREAS study areas. This data set contains the measurements from the tipping bucket rain gauges at the BOREAS NSA and SSA. These measurements were submitted in 15-minute and 1-hour intervals. Only the 15-minute interval data set was loaded into the data base tables. Data were collected from the tipping bucket gauges from mid-April until mid-October in 1994, 1995, and 1996. The data are available in tabular ASCII files.

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